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16. ABSTRACT The paper discusses a case study of radon diagnostics and mitigation procedures performed in a school researched by the U.S. EPA in New York State. It discusses building construction details, radon diagnostic measurements, mitigation system details, and post-mitigation radon levels. Elevated radon levels have been identified in school buildings throughout the U.S. and, as a result, the EPA has been researching radon reduction techniques for schools since early 1988. Initial research has addressed subslab depressurization, a successful radon reduction technique for many houses. Radon levels in schools can be influenced by the heating, ventilating, and air-conditioning (HVAC) system's effect on the pressure relationship of the building envelope. As a result, HVAC strategies for radon control have been used successfully in some schools.

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BUILDING HVAC/FOUNDATION DIAGNOSTICS FOR RADON MITIGATION IN SCHOOLS: PART 2 TECHNICAL SESSION T-20

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ABSTRACT

Elevated levels of radon have been identified in school buildings throughout the United States and, as a result, the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development has been researching radon reduction techniques for schools since early 1988. Initial research has addressed subslab depressurization, a successful radon reduction technique for many houses.

Radon levels in schools can be influenced by the heating, ventilating, and air-conditioning (HVAC) systems' effect on the pressure relationship of the building envelope. As a result, HVAC strategies for radon control have been used successfully in some schools. This Part 2 presentation focuses on a case study of the diagnostics and mitigation procedures performed in a school researched by the EPA in New York State. Building construction details, radon diagnostic measurements, mitigation system details, and post-mitigation radon levels are discussed.

BACKGROUND

Many scientists believe that children are at a greater risk of developing lung cancer from exposure to radon than adults for a number of reasons: they have smaller lung volumes and higher breathing rates than adults; their rapidly dividing cells may be more susceptible to radiation damage; and they have a longer life-span for latent cancers to develop. In order to reduce the potential health risks of radon exposure to children and those who work in schools, the U.S. Environmental Protection Agency (EPA) has been researching ways of reducing elevated levels of radon in school buildings.

Radon mitigation research in school buildings has shown that heating, ventilating, and air-conditioning (HVAC) systems in schools can dramatically influence the pressure relationship of the building envelope relative to its surroundings and, consequently, affect radon entry(1). If the HVAC system induces negative pressure in the building interior relative to the subslab area, radon entry into the building can be enhanced. Conversely, if the HVAC system pressurizes the building, creating positive pressure in the building relative to the subslab area, it can suppress radon entry as long as this pressure relationship exists. However, school buildings typically have areas such as laboratories, gymnasiums, locker rooms, auditoriums, cafeterias, kitchens, restrooms, and shops that are operated under negative pressure to exhaust chemicals or odors. Even if the classrooms are designed and operated under positive pressure, operation of exhaust fans may cause certain building

zones to be under negative pressure, potentially increasing radon entry in these areas. If pressurization through the HVAC system is under consideration as a long-term solution for radon control, proper operation and maintenance of the HVAC system are critical. Building pressurization with the HVAC system has been effective in reducing radon levels in some schools, depending on system design and operation.

Radon in schools and in houses is frequently reduced by depressurizing the subslab area(2). This technique -- referred to as subslab depressurization (SSD) -- works by inserting pipes through the concrete slab to access the crushed rock or soil beneath. A fan is used to reverse the pressure differential; that is, cause the soil side of the slab to be at lower pressure than the building interior. This reversed pressure relationship prevents radon-containing soil gas from entering the building. SSD systems are commonly more effective when the slab is underlain with a clean, coarse layer of aggregate which helps to extend the field of negative pressure under the slab. Measurements of the pressure fields under a slab are commonly referred to as pressure field extension (or subslab communication) measurements. The reader is referred to Radon Reduction Techniques in Schools -- Interim Technical Guidance for details(3).

If a SSD system is installed in a school to control radon entry, it must overcome any negative pressures that are generated by the HVAC system. Many schools that operate under positive pressure have actually installed SSD systems in order to control radon levels when the HVAC fans are not operating. This paper discusses experience with two approaches for radon reduction in a school researched by the EPA in New York: pressurization with the HVAC system and SSD.

CASE STUDY

This school, located in New York State, is approximately 4450 square meters (sq m) in area. The school foundation is a combination slab-on-grade (3600 sq m) and basement (750 sq m) with a small crawl space (less than 100 sq m). Two-day charcoal canister measurements made in December 1989 while the school was occupied showed that 12 of the 21 classrooms in the slab-on-grade section exceeded EPA's current guideline of 148 becquerels per cubic meter (Bq m^{-3}). The highest screening measurement in the slab-on-grade area was 770 Bq m^{-3}. Measurements in the basement ranged from a low of 230 Bq m^{-3} in the boiler room to a high of 1720 Bq m^{-3} in a storage area. Radon levels in a four-room office area in the basement averaged 1080 Bq m^{-3}. The crawl space, with a poured concrete floor, does not seem to be a major contributor to the school's radon problem.

Description of HVAC Systems

The HVAC system in the slab-on-grade section classrooms consists of individual room unit ventilators mounted on the outside wall in 19 of the classrooms and overhead in the other 2. The unit ventilators are rated at 470 liters per second (l/s), and the minimum and maximum capacities for outdoor air for these units are estimated to be about 80 and 140 l/s, respectively. Note that the New York State Education Department requires that classrooms be supplied 4.7 l/s of outdoor air per student only when the outdoor temperature is above 2°C. Consequently, outdoor air is typically not delivered to the classrooms during much of the winter season. (As a comparison, the most recent ASHRAE ventilation standard (4), 62-1989, recommends that 7 l/s of outdoor air per person be supplied to classrooms.) The HVAC system in this school also includes a number of exhaust fans in selected areas (e.g., corridors, kitchens) that cause the building to be under negative pressure when they are operating.

The HVAC system in the basement area is supplied by an air handling system that services only that area. Outdoor air intakes for this system have been disabled; however, some leakage of fresh air into the air handling system is evident. The amount of outdoor air leaking into the system has not yet been quantified.

Boiler room combustion air is supplied at a rate of about 1100 l/s with the boiler operating at low speed. With the boiler operating at high speed, no appreciable difference in makeup air volume was measured. This implies that the passive delivery system is undersized for the boilers when they are operating at high speed, causing additional depressurization of the basement area. The following sections summarize the radon diagnostic measurements performed in this school during the winter of 1989-1990 and subsequent installation of a SSD system in the basement. The slab-on-grade and basement areas are discussed separately.

Slab-on-Grade

To evaluate the potential effectiveness of a SSD system in the slab-on-grade area, subslab communication was measured in two classrooms with elevated radon levels located at opposite ends of the building. Since the slab was poured directly onto a mixture of tightly packed sand, silt, and clay, subslab communication was relatively poor and did not extend much beyond 4 meters (m). Consequently, mitigation by SSD would require many suction points since there are 12 slab-on-grade classrooms with elevated radon levels.

To investigate the potential for radon control by pressurization through operation of the unit ventilators, the outdoor air intakes for seven classrooms in one wing were opened to provide approximately 80 l/s of outdoor air during the occupied periods. (The HVAC system operates from about 7 a.m. to 1 p.m. and is on setback -- with no outdoor air -- during other times.) Spot differential pressure measurements under these conditions showed that the building interior was at a negative pressure of roughly 8 pascals (Pa) relative to the outdoors, even when the outdoor air intakes to the unit ventilators in one wing were opened to their minimum position. This indicates that the negative pressures induced by the exhaust fans and natural stack effect overwhelmed any pressurization by the unit ventilators.

It was not possible to evaluate the effect of the additional outdoor air on radon levels in the classrooms since the outdoor air was not adequately heated by the unit ventilators and, consequently, the rooms were uncomfortably cold. Current research is addressing additional mitigation options in the slab-on-grade section.

Basement

Subslab communication measurements in the basement showed that the subslab pressure field extended about 10 to 12 m from the suction point, indicating that a multi-point SSD system would likely control radon levels in the basement. Subslab communication in the basement seems to be much better than in the slab-on-grade section since the basement slab is underlain by a mixture of sand, silt, clay, and gravel (with the gravel facilitating subslab air flow). Continuous radon measurements collected in the basement office area during December 1989 averaged 1265 Bq m^3. Radon concentrations immediately prior to SSD system installation are not available due to equipment failure.

A five-point SSD system was installed in January 1990. The system ran passively for approximately 5 days. Continuous radon concentrations in the office averaged 773 Bq m^3, a reduction of about 40 percent from the continuous measurements collected in December 1989. On January 31, 1990, the SSD system was activated with a fan (rated at

190 1/s at 0 Pa). Continuous office radon concentrations quickly fell to an average of 414 Bq m^{-3}, a reduction of about 65 percent relative to the December levels and about 45 percent relative to the passive mode.

These initial radon measurements were made prior to excavation of pits at the suction points. Excavation of suction pits, although sometimes difficult depending on the subslab soil type and compaction, is often done to increase pressure field extension. An effort was made in this project to evaluate the effects of suction pit excavation on both pressure field extension and radon levels in the basement.

In early March 1990, suction pits were excavated at each suction point in the system to increase the negative pressure field beneath the slab. At this time, adjustments were also made to ball valves that had been installed in each of the five suction pipes in order to investigate the effects of restricting the flow through a given suction point. Following excavation of the pits and adjustment of the valves, negative pressures were measured beneath the slab in several areas where positive pressure was measured prior to digging the pits and adjusting the valves. Short-term (1-day) radon measurements in the office averaged 296 Bq m^{-3}, showing a reduction of 30 percent from levels prior to pit excavation and valve adjustment, and a reduction of about 75 percent from premitigation levels.

Figure 1 shows the differential pressure (in the subslab relative to building interior) versus distance from the suction point, both before and after the suction pit excavation. The valves were closed at the other four suction points so that P1 was the only point depressurizing the subslab. These data show that excavation of the suction pit decreased the pressures in the test holes close to the suction point and increased the strength and extent of pressure field at the distant holes. In fact, the farthest hole showed a slight positive pressure prior to excavation of the suction pit.

Figure 2 shows the pressure in the suction points under the following conditions: (1) all valves completely open and no suction pits, (2) all valves open and suction pits at all points, and (3) valves adjusted and suction pits at all points. Subslab differential pressure measurements with a micromanometer indicated that two of the suction points were taking advantage of foundation settling to increase the pressure field. Restriction of the valves at those two points helped to increase the pressure-field extension at the other three suction points. This resulted in a more optimal system design despite reduced static pressures at the suction points, as shown in Figure 2.

Additional steps to further decrease radon concentrations in the basement include supplying more combustion makeup air to the boilers to decrease the negative pressure being induced on the basement and introducing outdoor air into the air handling system. It is expected that these additional actions will decrease the basement radon concentrations below 148 Bq m^{-3}. The effects of these additional steps will be evaluated and presented at the conference.

CONCLUSIONS

The following conclusions may be drawn from this school in New York State currently being researched by the EPA:

1. If adequate makeup air is not provided in a school building, negative pressures caused by the HVAC system will enhance radon entry.

2. Although increasing outdoor air supply has been shown to reduce radon levels in some schools by pressurizing the building, this approach does not seem to be a viable year-round option with the unit ventilators in this school because of comfort.

3. Adequate combustion air must be supplied to the boiler room in order to reduce depressurization in the basement area.

4. Subslab pressure field extension can be improved by excavating suction pits and balancing flow through selected suction points.

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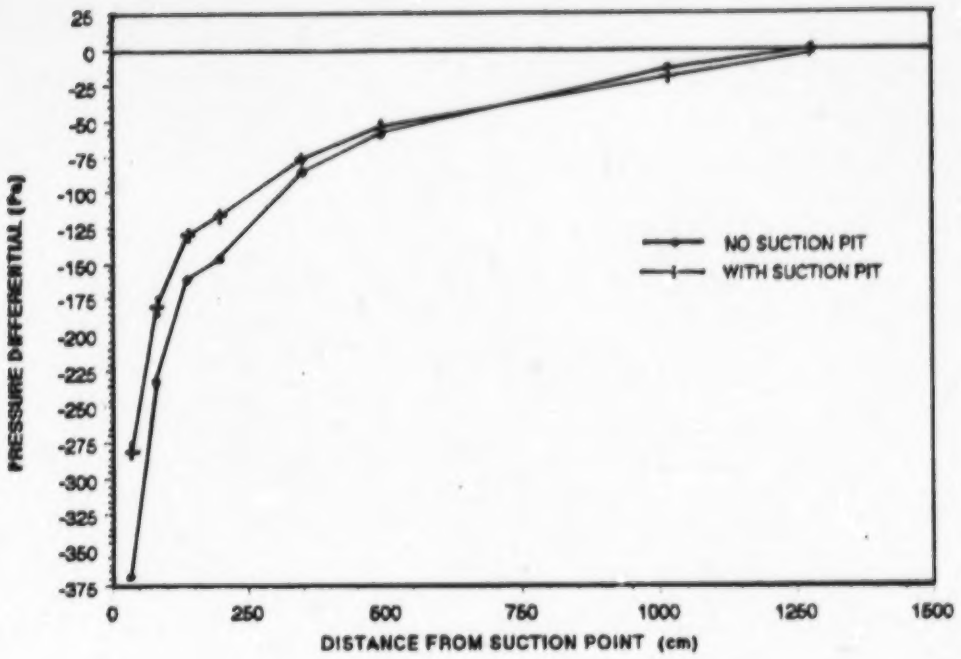

Figure 1. Pressure Differential Versus Distance From Suction Point.

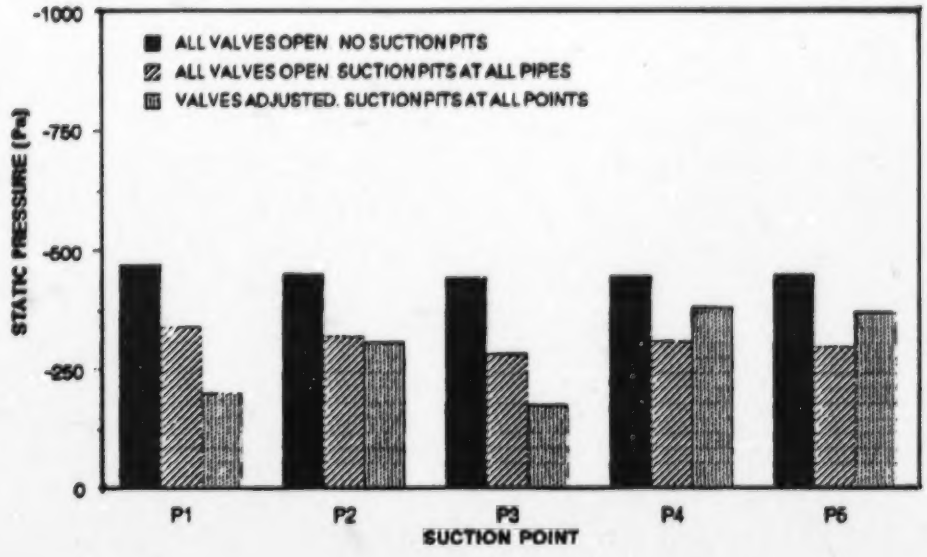

Figure 2. Suction Point Static Pressures.

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